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When Geochemistry encounters Archaeology

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The geochemical toolkit is pertinent to fields other than that of Earth and Planetary Sciences for which it is traditionally and commonly used. Here we show two recent examples of its application to numismatics, archaeology, and ancient history. High-precision Pb isotopes treated by novel statistical tools were used to provide data-based answers to important research questions revolving around the sources of silver used for money, jewelry, and other valuable artefacts in the ancient world.

In the first example, we studied remnants of the silver making up the largest treasure of precious metals reported in ancient Western history, namely that of Alexander the Great which he looted in his conquest of the Persian Empire, by analyzing a large set of ancient silver coins (*alexanders*, *sigloi*, Greek coins, and early Indian pseudo-coinage) for their Pb isotopic compositions. The high-precision data were treated using a new statistical approach in the form of calculated Pb model ages combined with cluster analysis and convex-hull theory, which allows the tracking of silver provenance with greater accuracy and precision than was previously possible when using only raw Pb isotope ratios and manually comparing artefacts with known ores on a one-to-one basis. Based on the Pb isotopic compositions of the analyzed silver coins compared with a ca. 6700-entry Pb isotope database on ores that we have compiled from the literature and our own work, we established that the bulk of the silver sources can be traced to the southern Aegean, Macedonia, and Thrace [1]. These origins had so-far only been the subject of speculation by numismatists, archaeologists, and historians, whereas now they are supported by high-precision isotope data and objective data analysis. Furthermore, we were able to confidently exclude India as a source [1], thereby putting to rest a long-standing debate around a possible Indian silver contribution to the Persian treasury.

In the second example [2], we measured high-precision Pb isotopes on pieces of hoarded *Hacksilber* (irregularly cut silver bullion) in the southern Levant, which facilitated trade and transactions from the beginning of the second millennium BCE until the late fourth century BCE. In a similar fashion to the first example, we treated the data using cluster analysis and convex-hull theory applied to Pb model ages calculated from measured high-precision Pb isotopic compositions. We found that exchanges between the Levant and the Aegean world continued at

least intermittently from the Late Bronze Age through to the Iron Age III. Importantly, contrary to common belief that silver trade had come to an end following the Late Bronze Age collapse, we demonstrated that despite the Aegean world dominating silver supply during the Iron Age, exchanges between the eastern and the western Mediterranean did not cease altogether. People around the Mediterranean remained connected with silver flowing to the Levant possibly as a result of trade or plunder.

[1] Blichert-Toft, J., de Callatay, F., Télouk, P., Albarède, F., submitted. *J. Archaeo. Meth. Theo*.

[2] Gentelli, L., Blichert-Toft, J., Davis, G., Gitler, H., Albarède, F., 2021. *J. Archaeo. Sci.* 134, Article 105472.